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INTERVIEW

THIN AS A RAIL, STRONG AS A ROCK

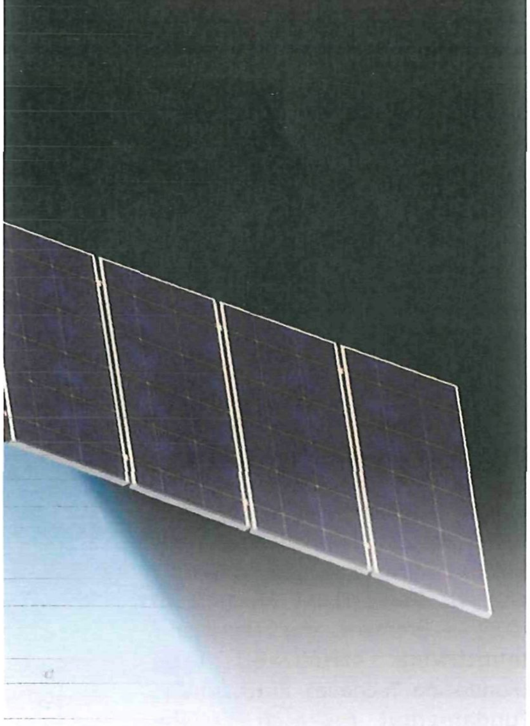
Satellite de-orbiting and re-entry is essential to halting the continuous increase in orbital space debris. The BETS project, which ends this month, is making waves with a new tether solution that is faster and more resistant to damage than any other existing technology.

A clean Earth orbit could be considered as a finish line on the journey towards improved space asset safety. But to get there stakeholders still need to answer three questions: how do we stop waste from accumulating in space, how do we get rid of existing debris and, once this is all done, how do we keep space tidy?

'Post-mission disposal' (PMD), which aims to move space assets to a disposal orbit or re-enter them into the atmosphere at end-of-life, will play a major role in answering the first and third questions. Though experts suggest that PMD alone will not prevent the debris population from growing uncontrolled — the so-called Kessler syndrome tells us that each collision generates a swarm of debris fragments, triggering a chain reaction — it will certainly prevent things from getting worse. But proving its efficiency will also build momentum for 'active debris removal' (ADR) by persuading businesses and governments that they are not investing in a lost cause.

Once limited to rockets, de-orbiting and re-entry technologies took a giant leap forward with the introduction of the bare tether concept in 1992. But until now these long conducting wires hanging from satellites have been highly vulnerable to

SPECIAL FEATURE CLEANING UP SPACE JUNK



"A de-orbit tether system of minimum complexity beats all other possible systems."

damage from abundant small space debris.

The BETS (Bare Electrodynamic Tethers) project might have found the solution to this issue: replacing traditional round tethers with tape, they observed that the probability of the tether being damaged by debris during de-orbiting differed by several orders of magnitude — in other words, it is hundreds of times less likely.

Prof. Juan Sanmartin, who coordinated the project, told us how the team's findings make de-orbiting tether systems more efficient, faster and resistant than any other existing technology.

What are the main objectives of the project?

Prof. Juan Sanmartin: The BETS project is focused on a single but ambitious long-term objective: proving that a de-orbit tether system of minimum complexity beats all other possible systems, whether propulsive systems (chemical, electrical) or just dragging systems augmented by deploying a sail. We aim to demonstrate that such a solution has the lowest system-to-satellite mass ratio and makes de-orbiting faster with better manoeuvrability, but also that it has a high reliability level and a capacity to survive space debris throughout operation. The project was determined to develop its concept up to Technology Readiness Level 4-5 — that is, validation in laboratory and relevant environment.

How does a space tether work exactly?

A space tether is a thin, multi-kilometre-long, conductive wire bridging a satellite and some opposite end mass. The tether frame is in motion relative to the co-rotating plasma and Earth's magnetic field. As a result, the highly conductive ambient plasma, which is equipotential in its own frame, presents, in the tether frame, a motional electric field of an order of 100 V/km, which is the product of (near) orbital velocity and the geomagnetic field. This allows plasma contactor devices to collect electrons at one polarised-positive (anodic) end and eject electrons at the opposite end, setting up a current along a standard, fully insulated tether. Lorentz drag on the magnetically induced tape current produces orbital decay of the satellite.

What kind of technological advances does BETS bring to the table?

The bare tether concept had taken away the insulation and had electrons collected over the anodic segment for a much more effective current collection. Ten years ago tether technology might have been said to face three main difficulties. One was the re-entry issue that Design for Demise had resolved years ahead of BETS. Another was the generally-acknowledged low probability of survival of round tethers when hit by small debris; which has given rise to the complex concept of multi-line 'tape' — we will call it 'fake tape' — made of thin round wires cross-connected to survive debris impacts. This concept also emerged before BETS was kicked off and has somehow been accepted as the solution to the tether survivability problem.

What we bring to the table is proof that a bare tape might withstand impact much more effectively than a bare round tether, due to both faster de-orbiting and the disparate character of width and thickness. This, along with the finding that real tape de-orbits much faster than 'fake tape', is a fundamental result in tether technology.

A third difficulty was the long de-orbit times high inclination orbits seemed to require. This was partly offset by detailed calculations under a detailed model of the geomagnetic field. It was further shown in BETS that the coupling of in-plane, off-plane oscillations, if bounded, helped de-orbiting by keeping the tether moderately away from the orbital plane.

You said this technology was much more efficient. How so?

Tethers use a dissipative mechanism quite different from air drag and can de-orbit in just a few months; also, tape tethers are much lighter than round tethers of equal length and perimeter, which can capture equal current. The three disparate tape dimensions allow easily scalable design to apply for arbitrary missions. Switching the cathodic contactor off-on allows manoeuvring to avoid catastrophic collisions with big tracked debris. Lorentz braking is as reliable as air drag. Tethers are still reasonably effective at high orbital inclinations, as mentioned above.

What are the next steps for the project, and follow-up plans after it ends?

We have multiple opportunities ahead of us. One of them is the fact that Horizon 2020 includes a topic for the in-orbit demonstration of de-orbiting a satellite at the end of its operational life.

Mr Gómez Molinero, CTO from Airbus Defence & Space Spain, manifested his interest in electrodynamic tethers at the 6th European Conference on Space Debris at ESOC/ESA (2012). Several contacts and meetings between BETS-UPM and Mr Gómez took place, where Mr Gómez was invited to make a presentation about a possible collaboration in the next H2020 call. Airbus would be interested in the use of bare electrodynamic tethers for de-orbiting the Multiple Payload Dispensers in the VEGA or Soyuz-Fregat Arianespace launchers, dispensers that it does build. He contacted Arianespace for that purpose, and one of his collaborators at Airbus started the preliminary design of such a demonstration mission under UPM supervision. A meeting with Arianespace is planned for this spring.

© Prof. Juan Sanmartin

Are you pleased with the results of your research?

We are. An important result from BETS was the determination of design criteria for sizing the three disparate dimensions of a tape tether — affecting the mass, ohmic effects, current-collection regime, self-magnetic field and survivability against debris in space under varying ambient conditions and as the tether loses altitude. A specific, thorough full code named BETsMA is now a Registered Design.

Other important results are innovative manufacturing, as well as ground-testing of basic tether-system hardware: Plasma Contactor (Colorado State University), Power Control Module (small company emxys), Deployment Mechanism (DLR — Bremen), and crosswise / lengthwise structured tape (Fundación Tecnalia). Furthermore, fundamental research at the Universitá di Padova and ONERA-Toulouse improved current knowledge of the basic physics underlying tether technology.

Have any governments shown interest in deploying the technology yet?

There is indeed a potential impact at a political, international level. The increase in the number of countries with direct access to space makes the present approach to the debris problem not just European or national, but fully international. To guarantee an effective implementation of de-orbiting new satellites at end-of-life, international consensus is required, in effect resting on UN space governance. The project could certainly lead to exploitation of leading-edge technology by companies in Europe. Ultimately, however, it could have a political success comparable to its commercial one.

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